Psychrometry

Psychometry

- The psychrometry is that branch of engineering science, which deals with the study of moist air i.e. dry air mixed with water vapour or humidity.
- It also includes the study of behaviour of dry air and water vapour mixture under various sets of conditions.
- Though the earths atmosphere is a mixture of gases including nitrogen, oxygen, argon and carbon dioxide, yet for the purpose of psychrometry, it is considered to be a mixture of dry air and water vapour only.

Psychometric terms

- Dry air
- Moist air
- Saturated air
- Dry bulb temperature
- Wet bulb temperature
- Dew point temperature
- Wet bulb depression
- Dew point depression
- Specific humididty
- Degree of saturation
- Absolute humidity
- Relative humidity
- Enathalpy

Psychometric terms

- **Dry air:** The dry air is considered as a mixture of nitrogen and oxygen neglecting the small percentages of other gases. The volumetric composition of air is 79% nitrogen and 21% oxygen and the molecular weight of dry air is taken as 29 approximately.

- **Moist air:** It is a mixture of dry air and water vapour. The quantity of water vapour present in the air depends upon the temperature of air and its quantity may change from zero to maximum.

Psychometry

- **Water vapour**: The water vapour present in air is known as moisture and its quantity on air is known an important factor in all air conditioning systems.
- **Saturated air:** The mixture of air and water vapour at a given temperature is said to be saturated when it contains maximum amount of water vapour that it can hold. If the temperature of mixture of air and water vapour is above the saturation temperature of the water vapour, the vapour is called superheated vapour.

Psychometry

- **Dry Bulb temperature**: The temperature of air measured by ordinary thermometer is called as dry bulb temperature.

- **Wet bulb temperature**: The temperature measured by the thermometer when is bulb is covered with wet cloth and is exposed to a current of moving air is known as wet bulb temperature.
- The difference between the wet bulb temperature and dry bulb temperature is known as wet bulb depression. Wet bulb depression becomes zero when the air is fully saturated.

- **Dew point temperature**: The temperature of the air is reduced by continuous cooling than the water vapour in the air will start condensing at a particular temperature. The temperature at which the condensing starts is known as dew point temperature.
- The difference between the dry bulb temperature and dew point temperature is known as dew point depression.

Psychometry

- **Specific humidity (humidity ratio):** It is the mass of water vapour present per kg of dry air. It is given in kg per kg of dry air.

- **Absolute humidity:** The weight of water vapour in unit volume of air is known as absolute humidity.

- **Relative Hummidity**: The relative humidity is defined as the ratio of actual mass of a water vapour in a given volume to the mass of water apour if the air is saturated at the same temperature.

- **Degree of saturation:** The degree of saturation is defined as the ratio of mass of water vapour associated with unit mass of dry air to mass of water vapour associated with unit mass of dry air saturated at the same temperature.

Psychometry

- **Sensible heat of air**: The quantity of heat which can be measured by measuring the dry bulb temperature of air is known as sensible heat.

- **Total heat**: The total heat of the humid air is the sum of the sensible heat of the dry air and sensible and latent heat of the water vapour associated with the dry air.

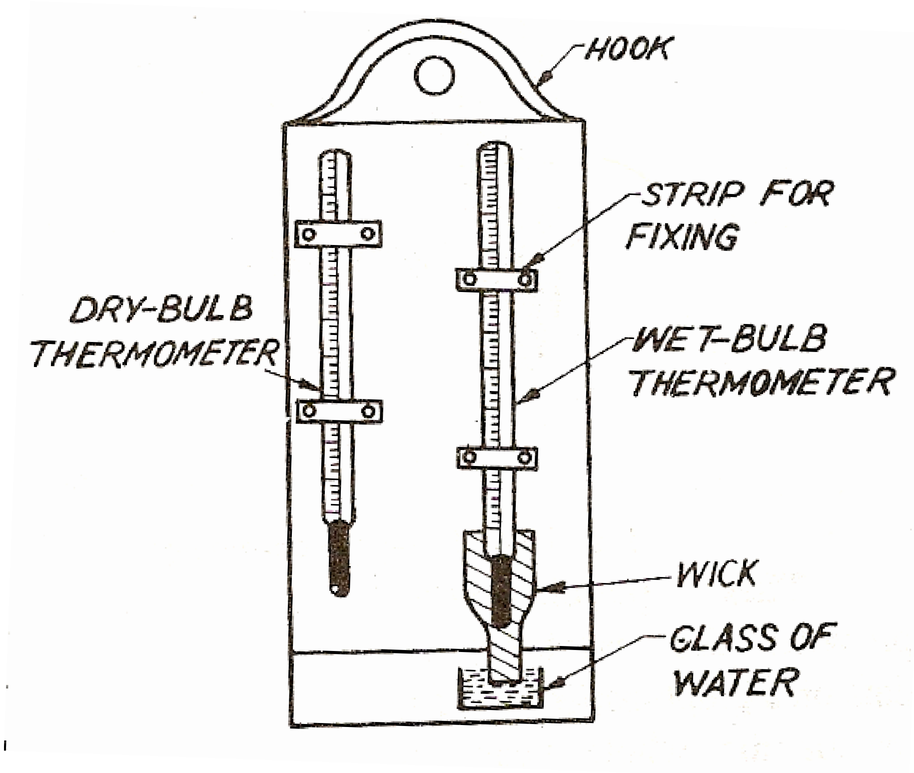
- **Humid specific volume:** The volume of the mixture per kg of dry air in the mixture, expressed in cubic meters, is known as humid specific volume.

Psychometer

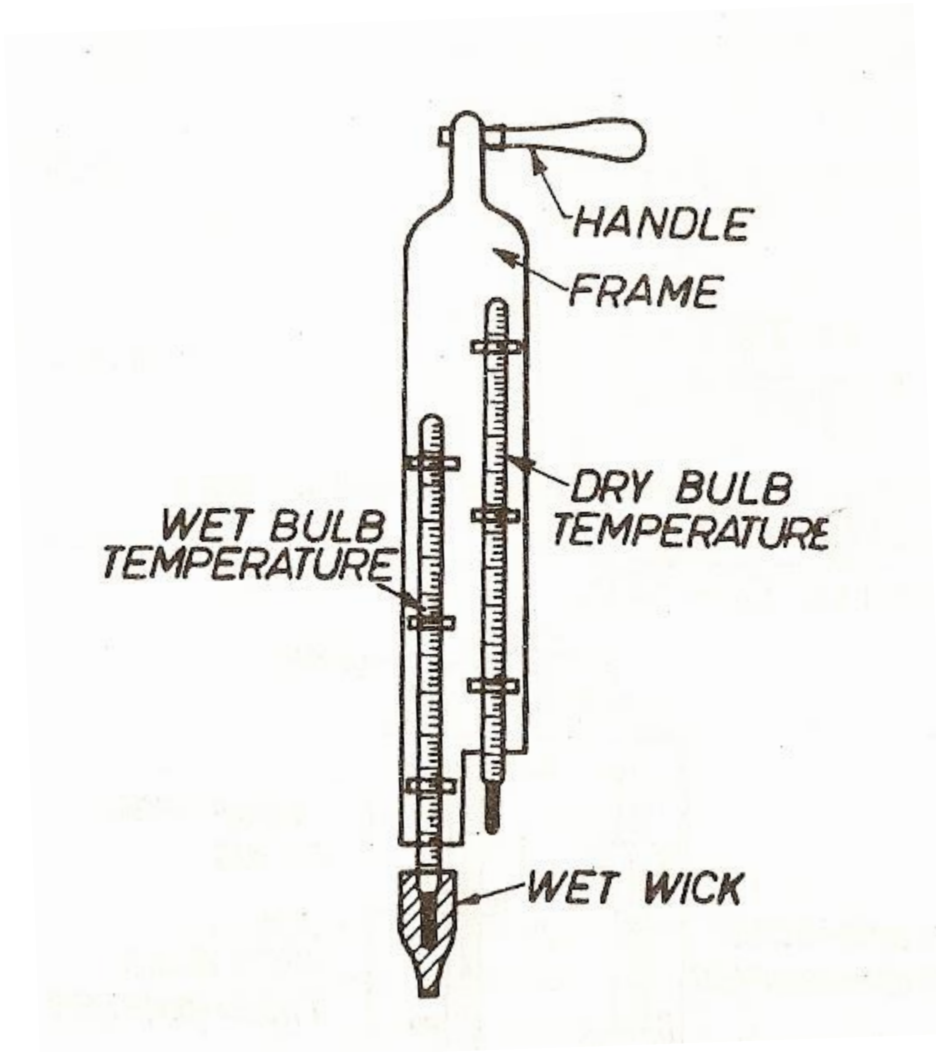
- The equipments used for measuring the dry bulb temperature and wet bulb temperature simultaneously is known as psychrometer.
- The different types of psychrometers used are described below.
  - Laboratory psychrometer
  - Sling psychrometer
  - Aspirating psychrometer
  - Continous recording psychrometer

Laboratory psychrometer

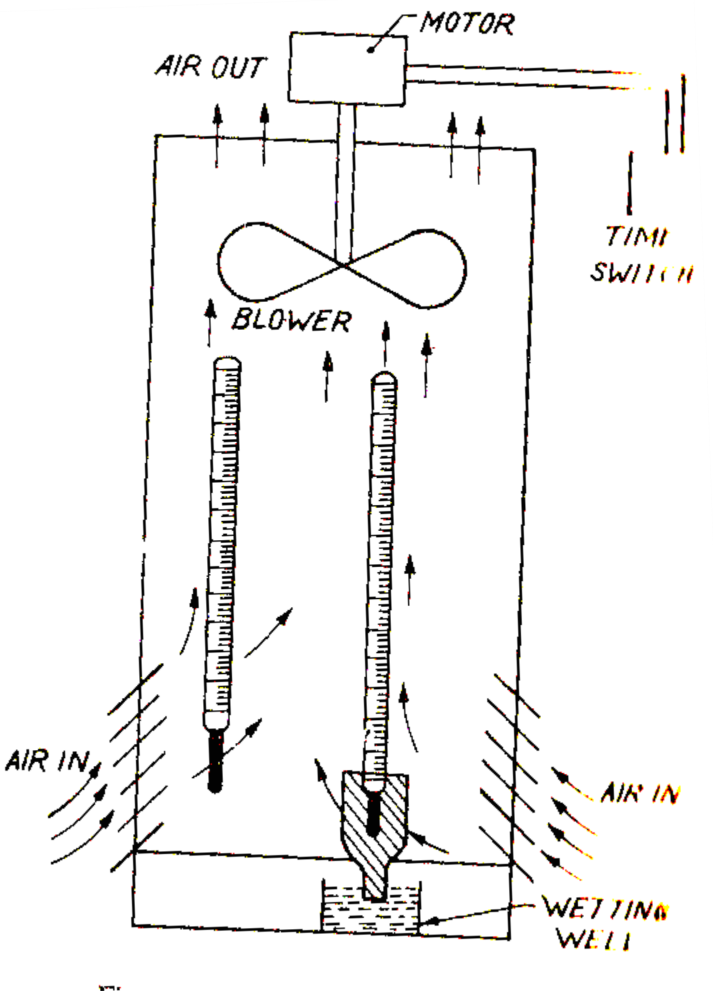
This is a simplest type of psychrometer as shown in Fig. this type of psychrometer is generally hung on the wall which always reads the dry bulb and wet bulb temperatures of the surrounding air.



Sling psychrometer



Aspirating Psychrometer



Psychrometric relations

Sl. No	Psychrometric term	Equation
1	Specific humidity	$W = 0.622\left(\frac{P_v}{P_b - P_v}\right)$
2	Relative humidity	$Ø = \frac{m_v}{m_s} = \frac{P_v}{P_s}$
3	Degree of saturation	$\mu = \frac{W}{W_s}$
4	Pressure of water vapour	$Pv = P_w - \frac{(P_b - P_w)(t_d - t_w)}{1544 - 1.44t_w}$
5	Enthalpy	$h = 1.022t_d + W(h_{fgdp} + 2.3t_{dp})$
6	Absolute humidity	$\frac{W(P_b - P_v)}{R_a T_d}$

TABLE 1

Staturated Water and Steam (Temperature) Tables

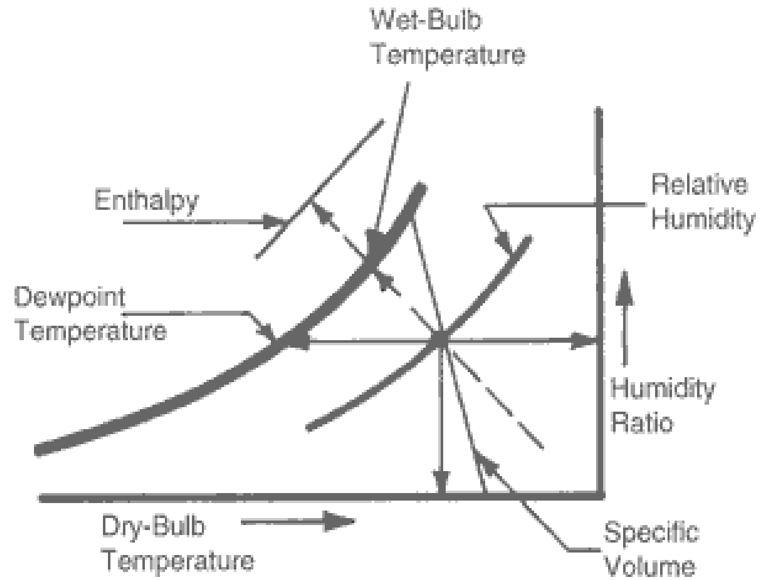
Temperature in°C	Absolute pressure in bar	Specific volume in m^3/kg		Specific enthalpy in kJ/kg			Specific entropy in kJ/kg K		
		Water	Steam	Water	Evaporation (h_{fg})	Steam	Water	Evaporation (s_{fg})	Steam
(t)	(p)	(v_f)	(v_g)	(h_f)		(h_g)	(s_f)		(s_g)
0	0.006 11	0.001 000	206.31	0.0	2 501.6	2 501.6	0.000	9.158	9.158
1	0.006 57	0.001 000	192.61	4.2	2 499.2	2 503.4	0.015	9.116	9.131
2	0.007 06	0.001 000	179.92	8.4	2 496.8	2 505.2	0.031	9.074	9.105
3	0.007 58	0.001 000	168.17	12.6	2 494.5	2 507.1	0.046	9.033	9.079
4	0.008 13	0.001 000	157.27	16.8	2 492.1	2 508.9	0.061	8.992	9.053
5	0.008 72	0.001 000	147.16	21.0	2 489.7	2 510.7	0.076	8.951	9.027
6	0.009 35	0.001 000	137.78	25.2	2 487.4	2 512.6	0.091	8.911	9.002
7	0.010 01	0.001 000	129.06	29.4	2 485.0	2 514.4	0.106	8.870	8.976
8	0.010 72	0.001 000	120.97	33.6	2 482.6	2 516.2	0.121	8.830	8.951
9	0.011 47	0.001 000	113.44	37.8	2 480.3	2 518.1	0.136	8.791	8.927
10	0.012 27	0.001 000	106.43	42.0	2 477.9	2 519.9	0.151	8.751	8.902
11	0.013 12	0.001 000	99.909	46.2	2 475.5	2 521.7	0.166	8.712	8.878
12	0.014 01	0.001 000	93.835	50.4	2 473.2	2 523.6	0.181	8.673	8.854
13	0.014 97	0.001 001	88.176	54.6	2 470.8	2 525.4	0.195	8.635	8.830
14	0.015 97	0.001 001	82.900	58.7	2 468.5	2 527.2	0.210	8.597	8.806
15	0.017 04	0.001 001	77.978	62.9	2 466.1	2 529.1	0.224	8.559	8.783
16	0.018 17	0.001 001	73.384	67.1	2 463.8	2 530.9	0.239	8.520	8.759
17	0.019 36	0.001 001	69.095	71.3	2 461.4	2 532.7	0.253	8.483	8.736
18	0.020 62	0.001 001	65.087	75.5	2 459.0	2 534.5	0.268	8.446	8.714
19	0.021 96	0.001 002	61.341	79.7	2 456.7	2 536.4	0.282	8.409	8.691

Saturated Water and Steam (Temperature) Tables

(t)	(p)	(v_f)	(v_g)	(h_f)	(h_{fg})	(h_g)	(s_f)	(s_{fg})	(s_g)
20	0.023 37	0.001 002	57.838	83.9	2 454.3	2 538.2	0.296	8.372	8.668
21	0.024 85	0.001 002	54.561	88.0	2 452.0	2 540.0	0.310	8.336	8.646
22	0.026 42	0.001 002	51.492	92.2	2 449.6	2 541.8	0.325	8.299	8.624
23	0.028 08	0.001 002	48.619	96.4	2 447.2	2 543.6	0.339	8.263	8.602
24	0.029 82	0.001 002	45.926	100.6	2 444.9	2 545.5	0.353	8.228	8.581
25	0.031 66	0.001 003	43.402	104.8	2 442.5	2 547.3	0.367	8.192	8.559
26	0.033 60	0.001 003	41.034	108.9	2 440.2	2 549.1	0.381	8.157	8.538
27	0.035 64	0.001 003	38.813	113.1	2 437.8	2 550.9	0.395	8.122	8.517
28	0.037 78	0.001 004	36.728	117.3	2 435.4	2 552.7	0.409	8.087	8.496
29	0.040 04	0.001 004	34.769	121.5	2 433.1	2 554.5	0.423	8.052	8.475
30	0.042 42	0.001 004	32.929	125.7	2 430.7	2 556.4	0.437	8.018	8.455
31	0.044 91	0.001 005	31.199	129.8	2 428.3	2 558.2	0.450	7.984	8.434
32	0.047 53	0.001 005	29.572	134.0	2 425.9	2 560.0	0.464	7.950	8.414
33	0.050 29	0.001 005	28.042	138.2	2 423.6	2 561.8	0.478	7.916	8.394
34	0.053 18	0.001 006	26.601	142.4	2 421.2	2 563.6	0.491	7.883	8.374
35	0.056 22	0.001 006	25.245	146.6	2 418.8	2 565.4	0.505	7.849	8.354
36	0.059 40	0.001 006	23.967	150.7	2 416.4	2 567.2	0.518	7.817	8.335
37	0.062 74	0.001 007	22.763	154.9	2 414.1	2 569.0	0.532	7.783	8.315
38	0.066 24	0.001 007	21.627	159.1	2 411.7	2 570.8	0.545	7.751	8.296
39	0.069 91	0.001 007	20.557	163.3	2 409.3	2 572.6	0.559	7.718	8.277
40	0.073 75	0.001 008	19.546	167.5	2 406.9	2 574.4	0.572	7.686	8.258
41	0.077 77	0.001 008	18.592	171.6	2 404.5	2 576.2	0.585	7.654	8.239
42	0.081 99	0.001 009	17.692	175.8	2 402.1	2 577.9	0.599	7.622	8.221
[illegible]	[illegible]	[illegible]	16.841	180.0	2 399.7	2 579.7	0.612	7.591	8.203

Psychrometric chart

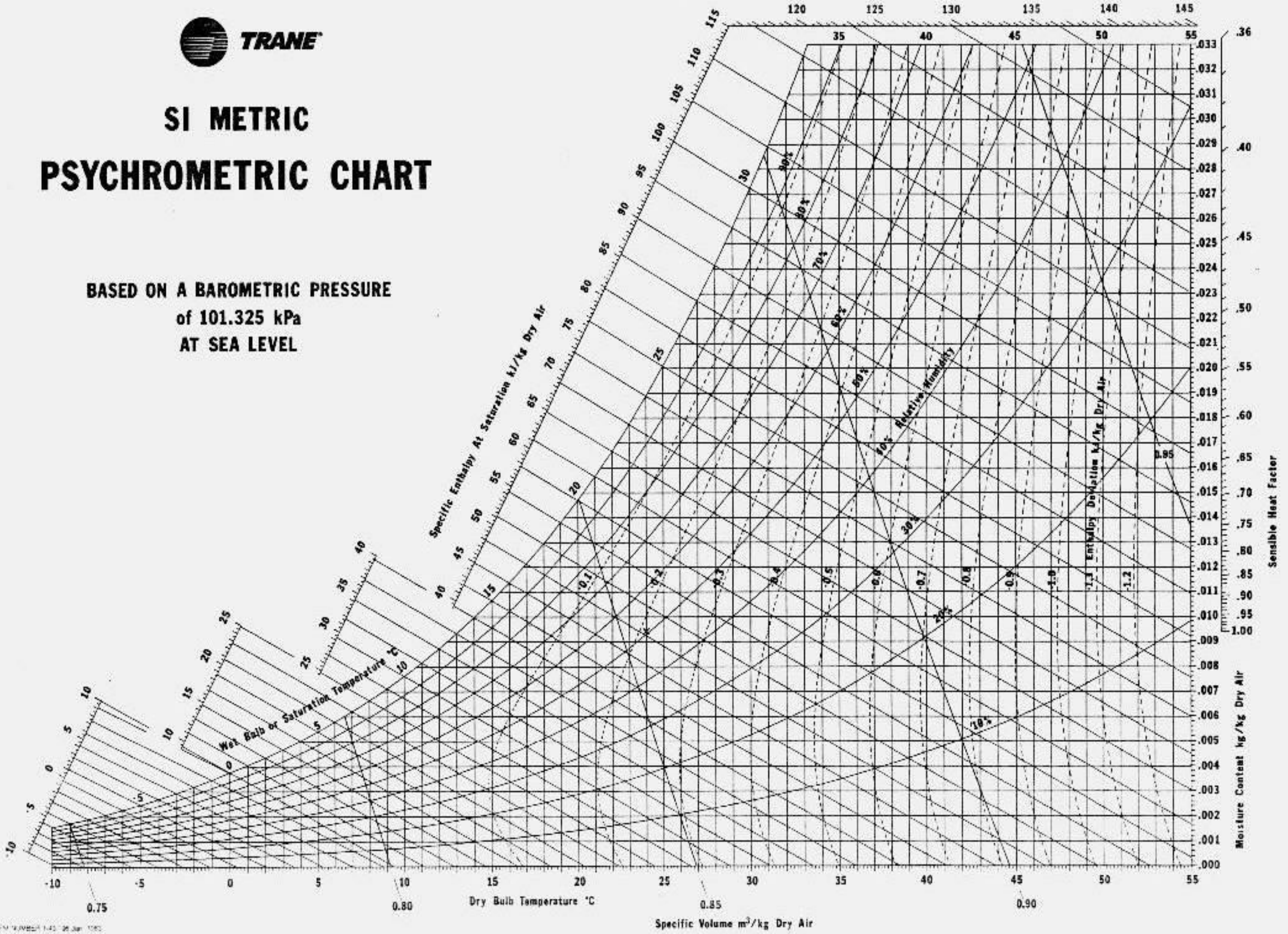
- It is a graphical representation of various thermodynamic properties of moist air.
- The psychrometric chart is very useful for finding out the properties of air (which are required in the fied of air conditioning) and eliminate lot of calculations.
- There is a slight variation in the charts prepared by different air conditioning manufactures but basically they are all alike.
- The psychrometric chart is normally drawn for standard atmospheric pressure of 760mm of Hg (or 1.01325 bar).

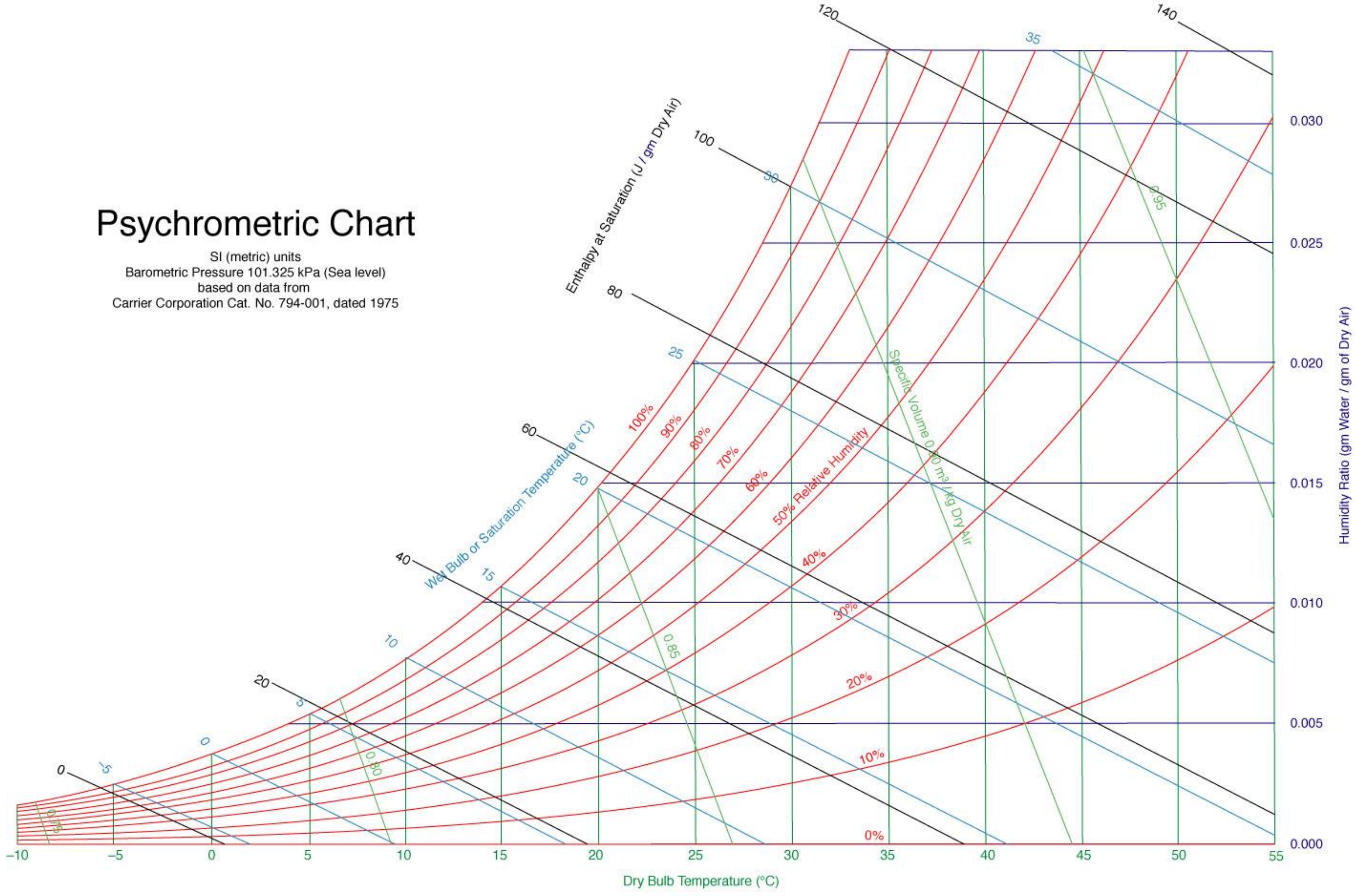


TRANE

SI METRIC
PSYCHROMETRIC CHART

BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL

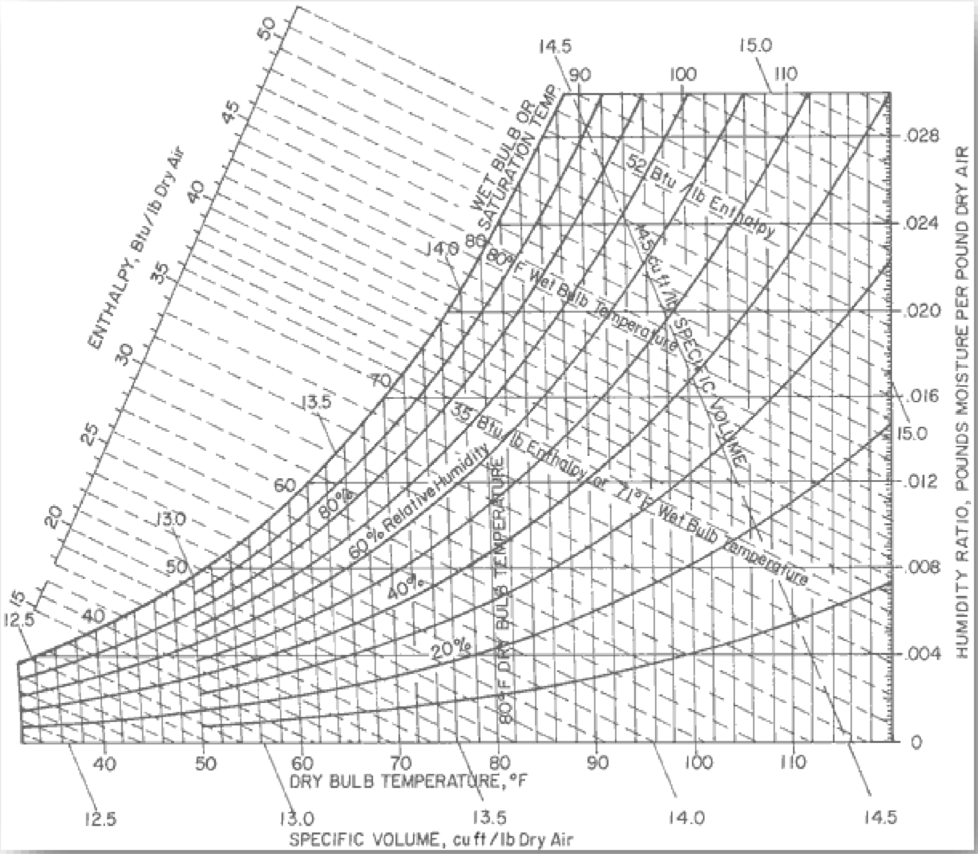


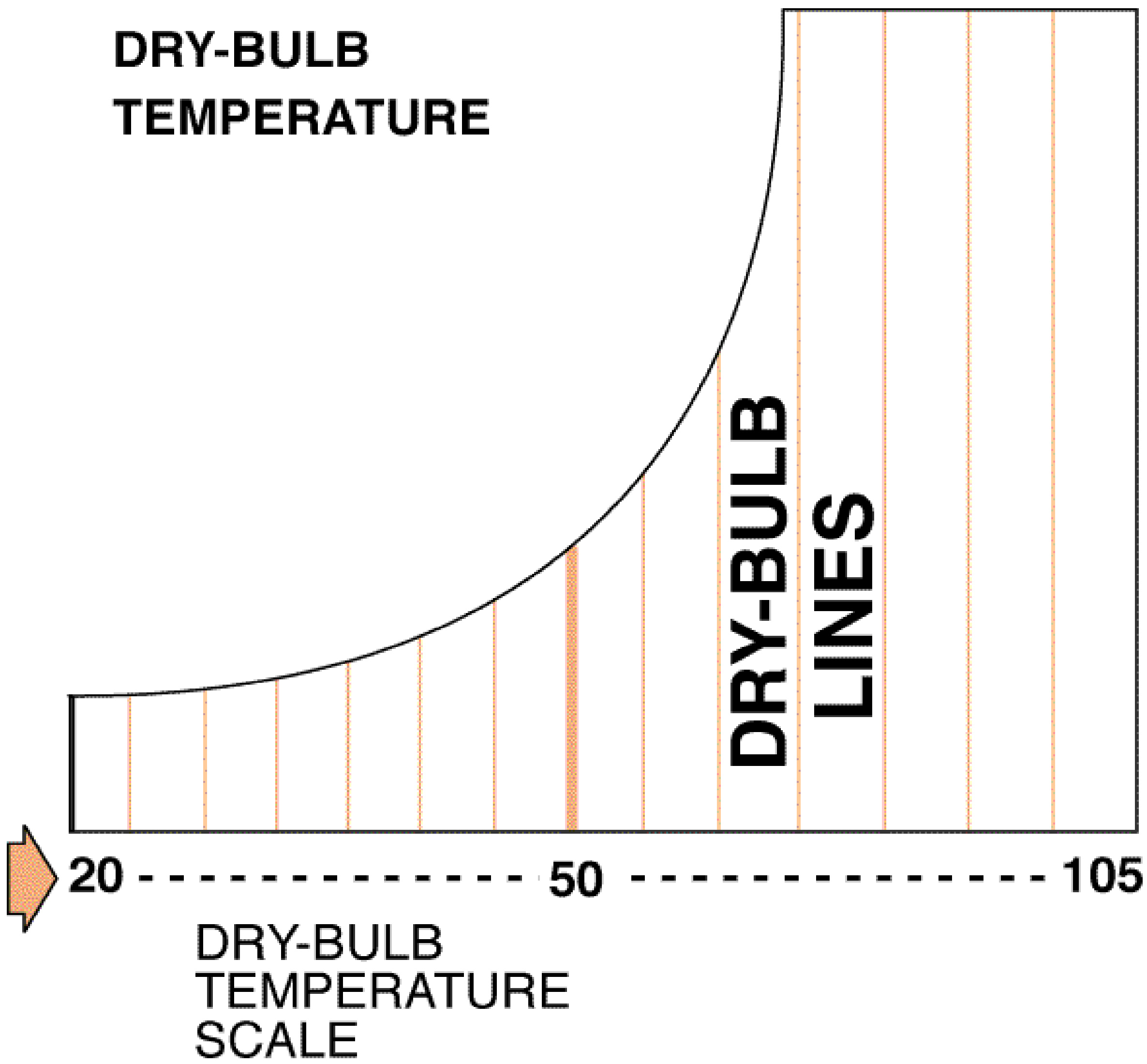


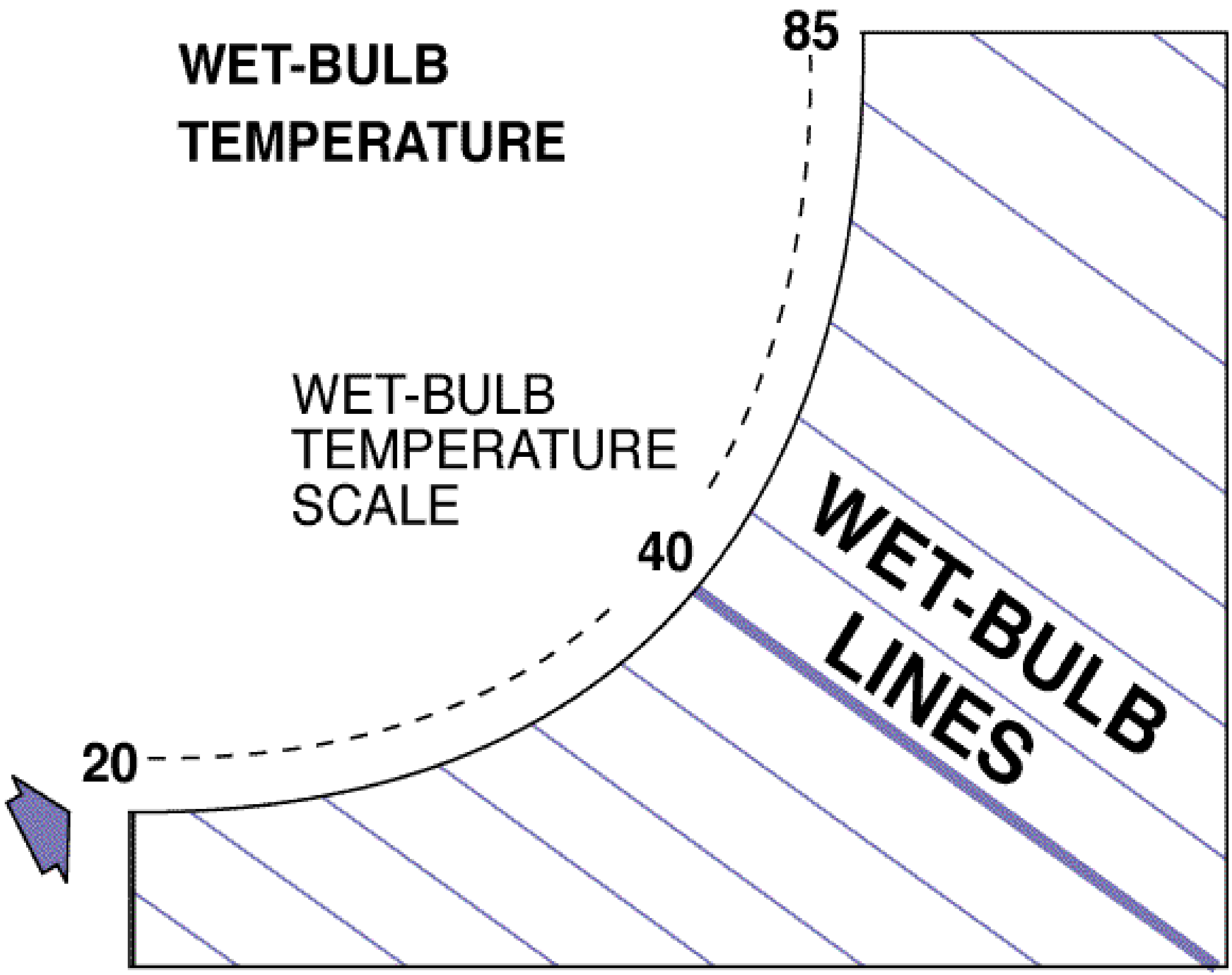
Psychrometric Chart
SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975
Enthalpy at Saturation (J / gm Dry Air)
Wet Bulb or Saturation Temperature (°C)
50% Relative Humidity
Specific Volume 0.90 m³ / kg Dry Air
Humidity Ratio (gm Water / gm of Dry Air)
Dry Bulb Temperature (°C)
100% 90% 80% 70% 60% 40% 30% 20% 10% 0%
0.000 0.005 0.010 0.015 0.020 0.025 0.030
−10 −5 0 5 10 15 20 25 30 35 40 45 50 55
0 20 40 60 80 100 120 140

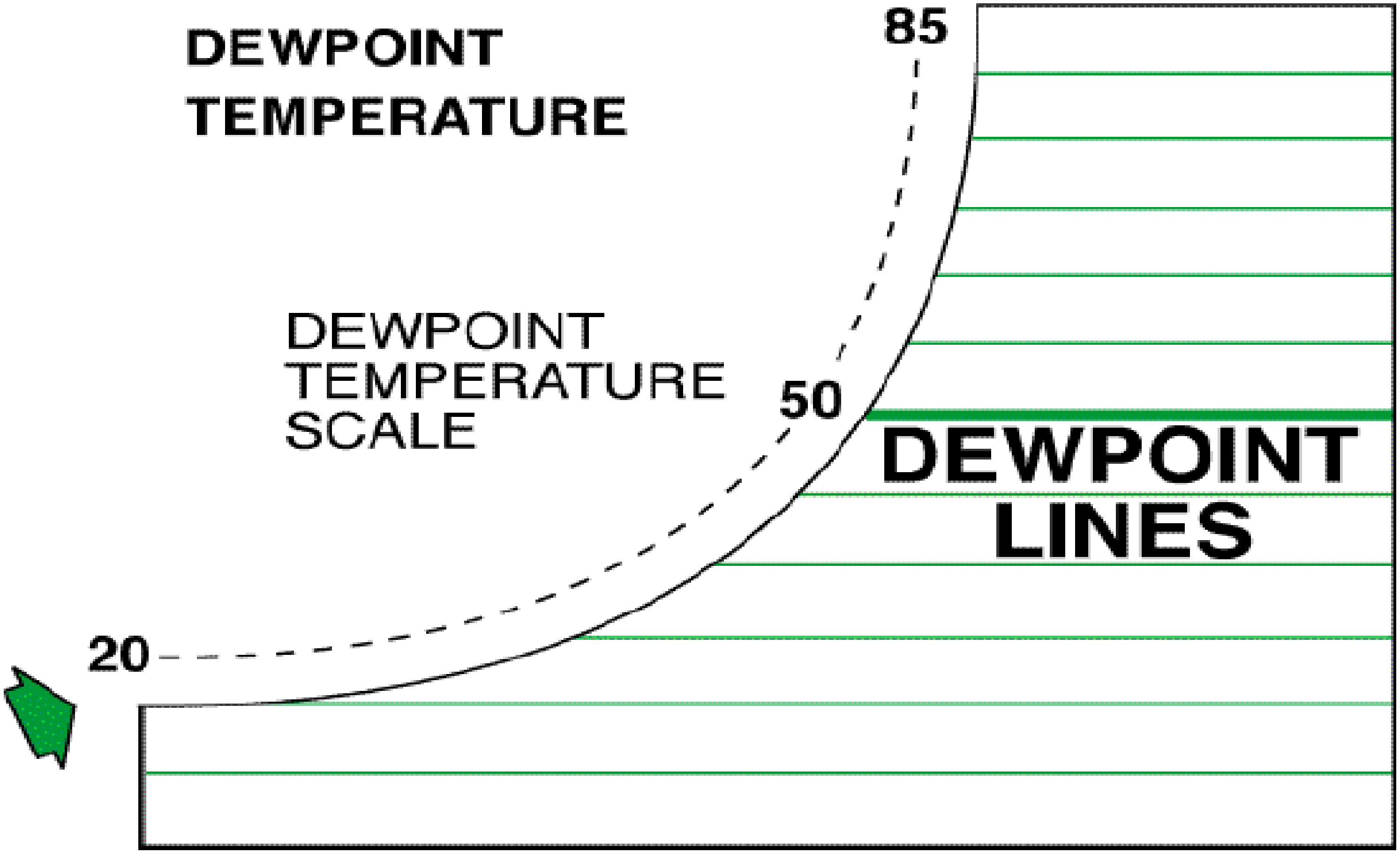
Psychrometric properties

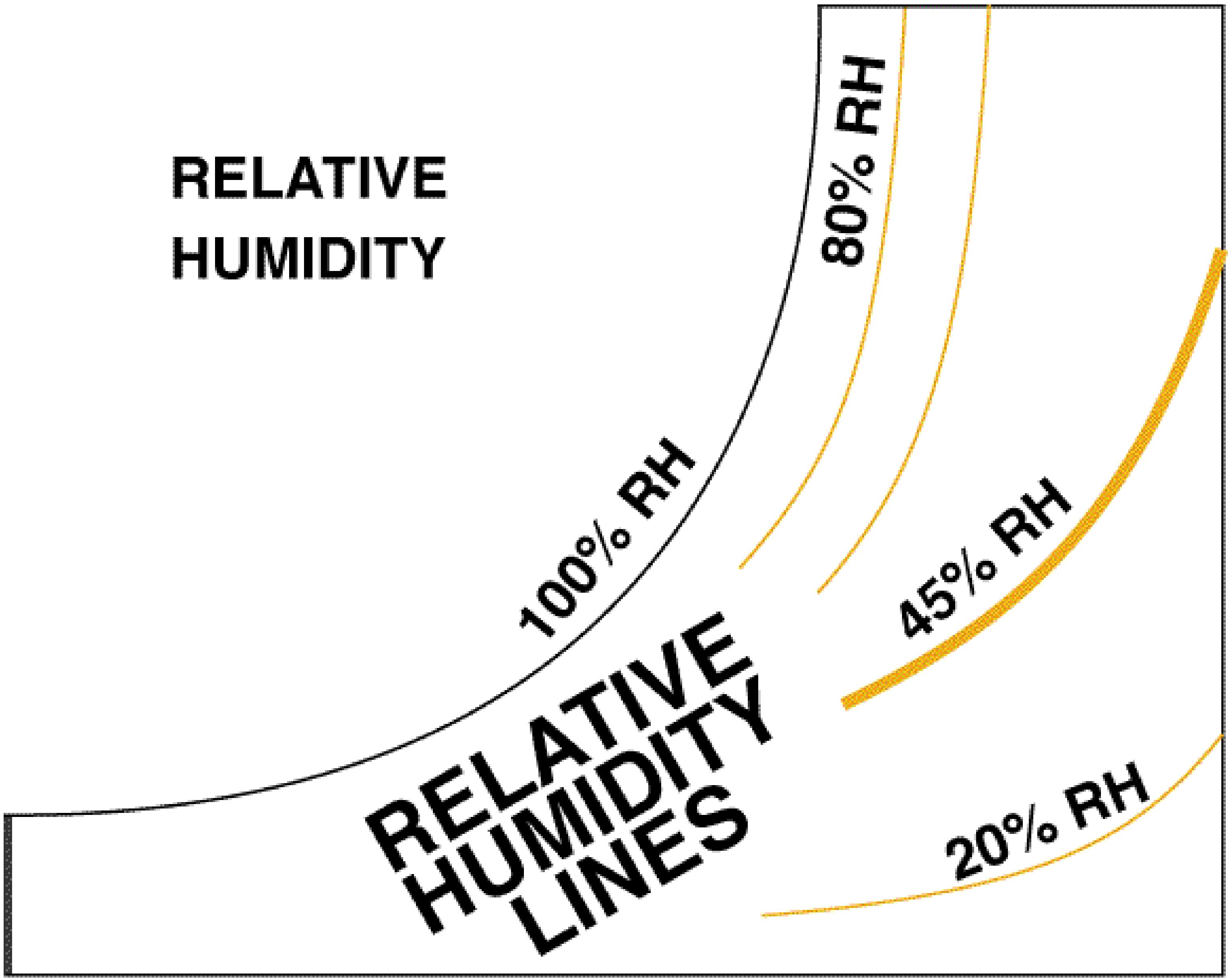
- Dry bulb temp lines
- Wet bulb temp lines
- Dew point temp lines
- Relative humidity curve
- Humidity ratio lines
- Absolute humidity lines
- Specific volume lines

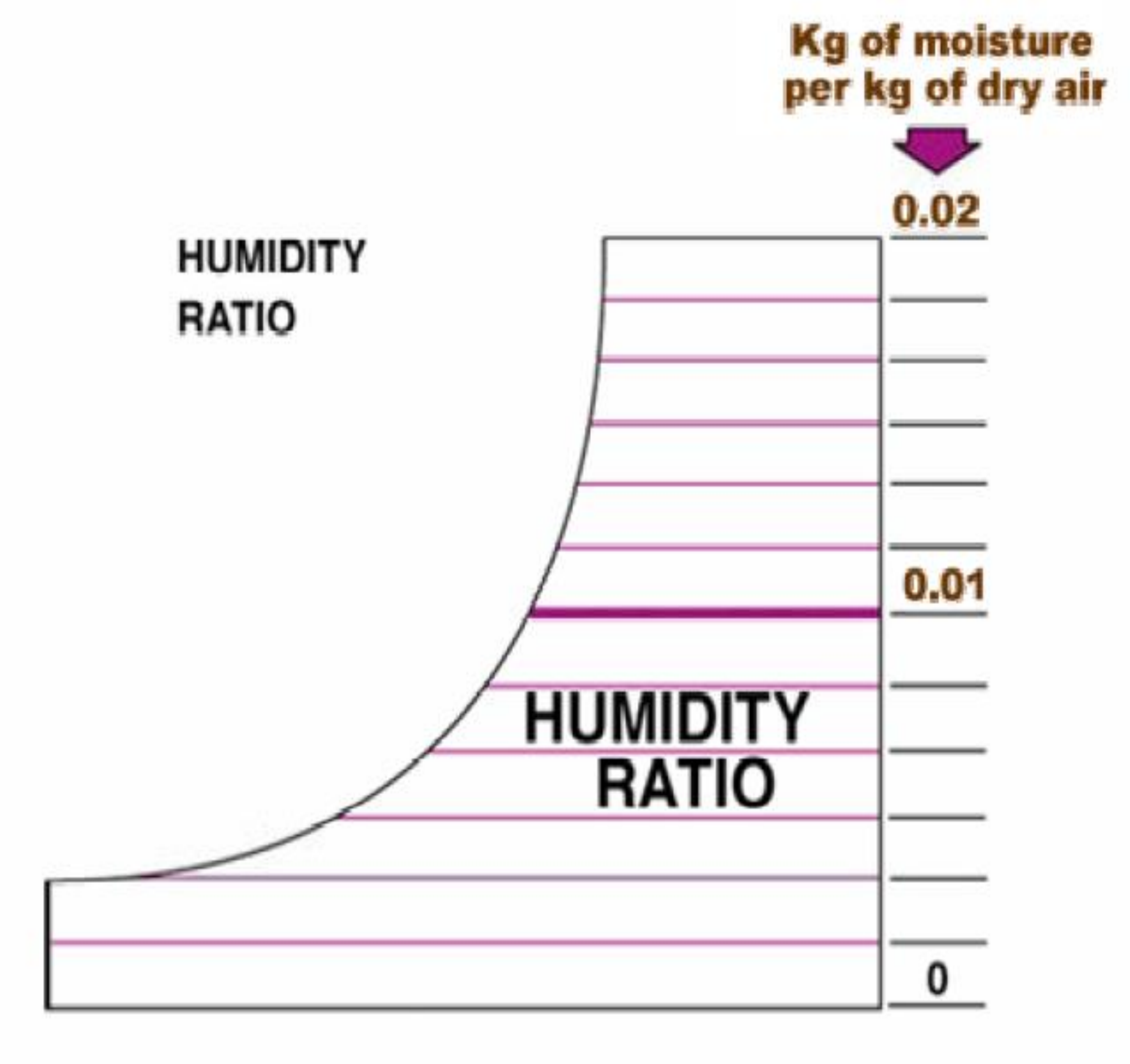


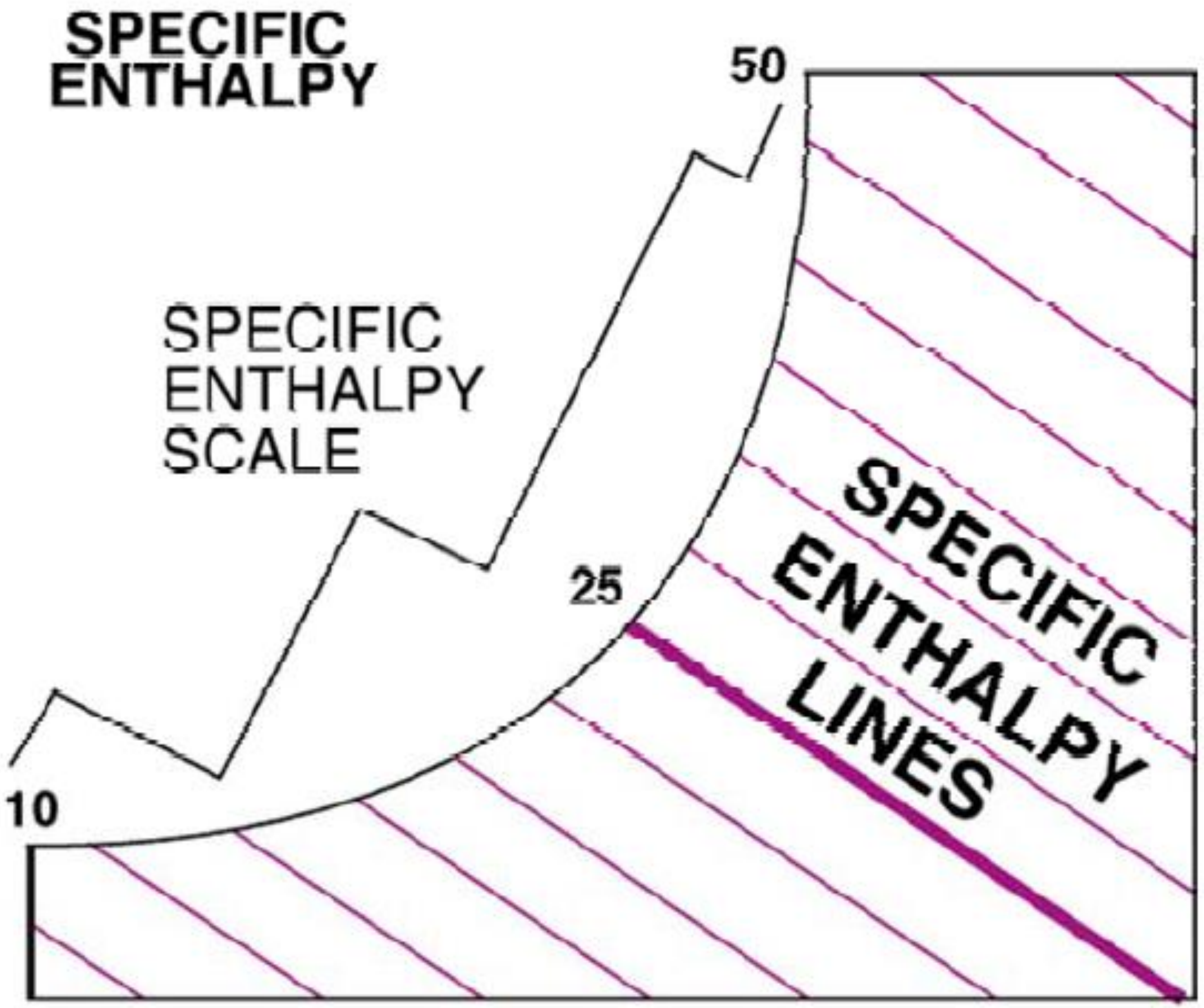

DRY-BULB
TEMPERATURE
DRY-BULB
LINES
20
50
105
DRY-BULB
TEMPERATURE
SCALE


WET-BULB
TEMPERATURE
85
WET-BULB
TEMPERATURE
SCALE
40
20
WET-BULB
LINES

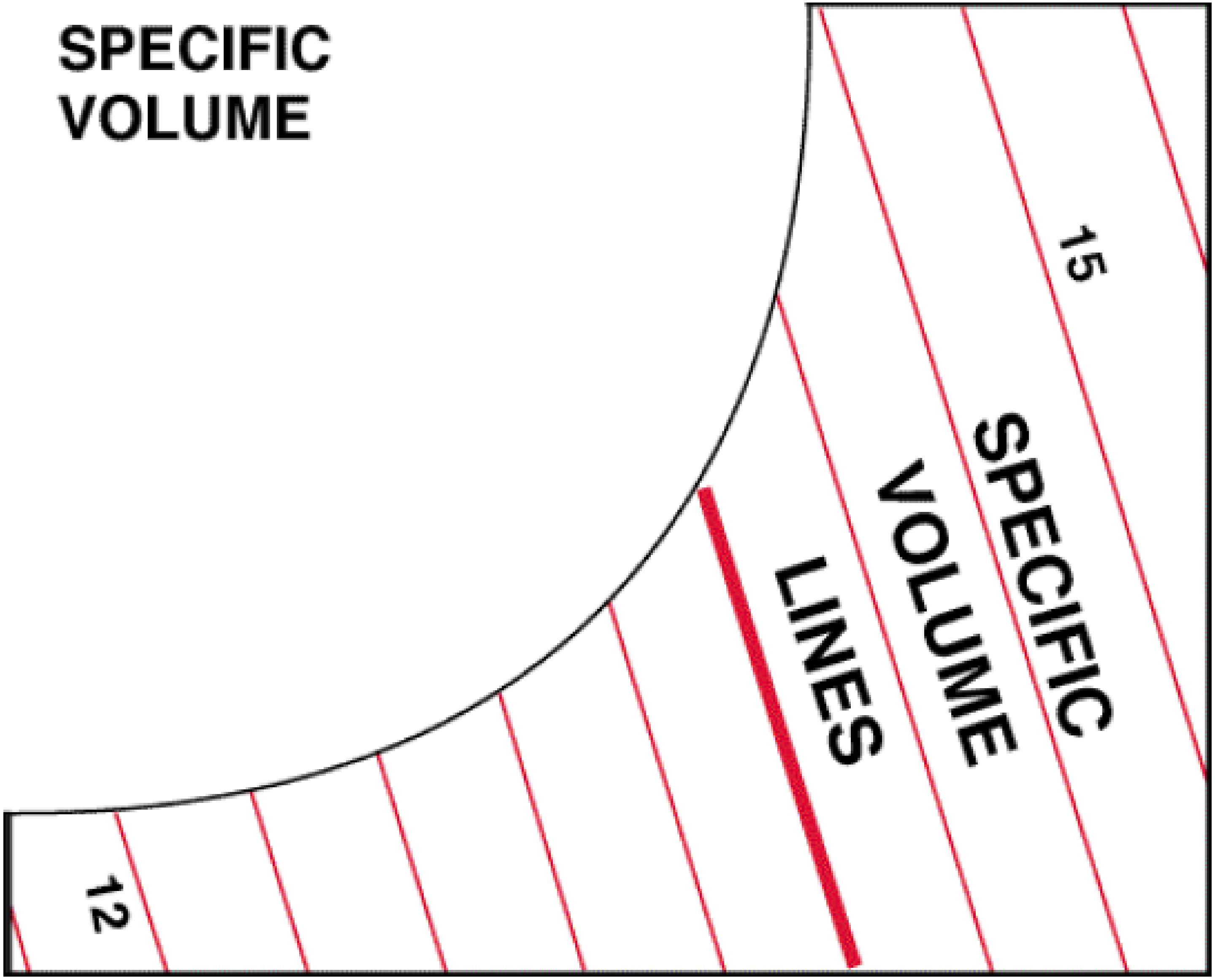

DEWPOINT
TEMPERATURE
85
DEWPOINT
TEMPERATURE
SCALE
50
DEWPOINT
LINES
20

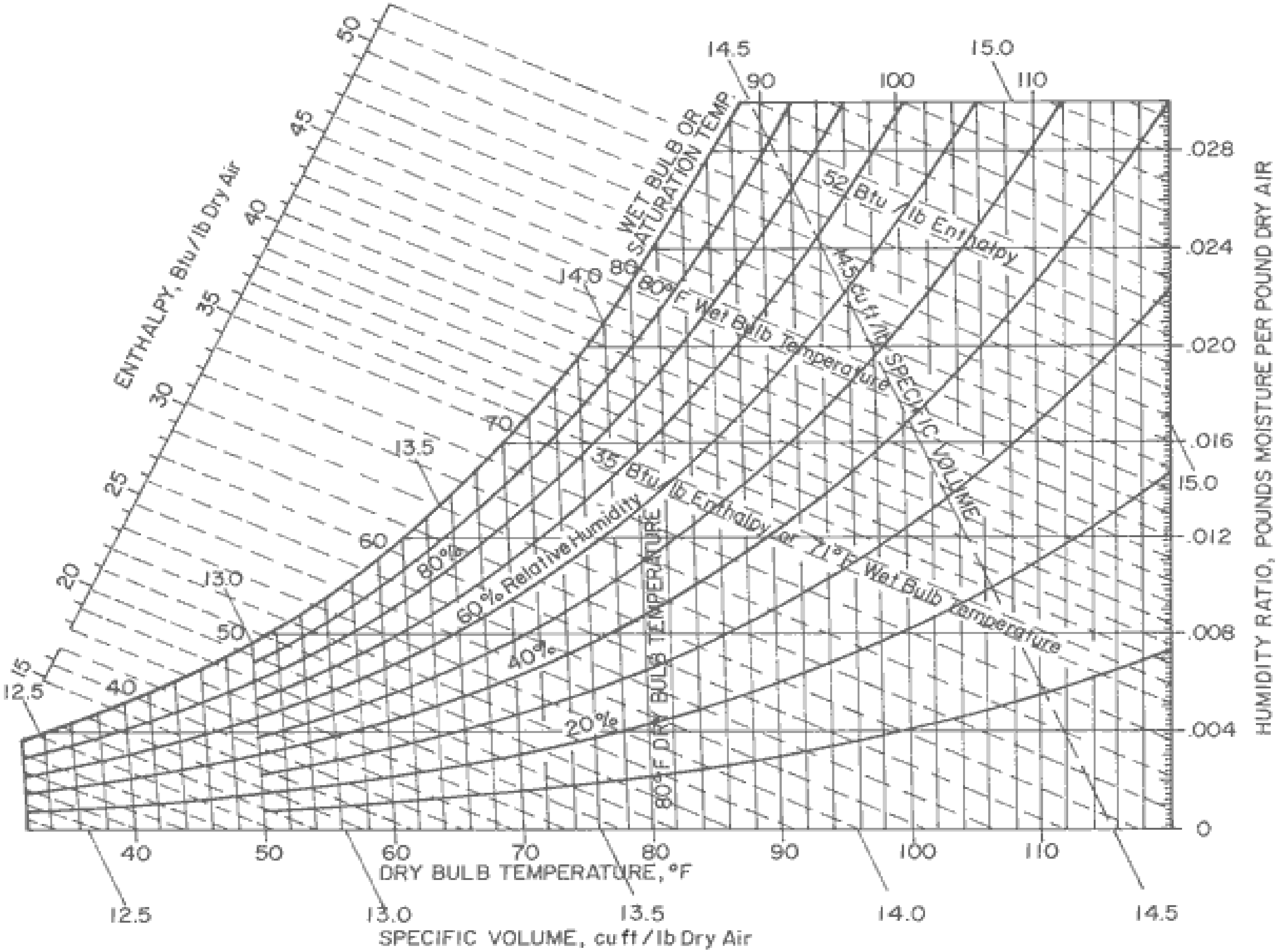

RELATIVE
HUMIDITY
100% RH
80% RH
45% RH
20% RH
RELATIVE
HUMIDITY
LINES


Kg of moisture
per kg of dry air
0.02
HUMIDITY
RATIO
0.01
HUMIDITY
RATIO
0


SPECIFIC ENTHALPY
50
SPECIFIC ENTHALPY SCALE
25
10
SPECIFIC ENTHALPY LINES

SPECIFIC VOLUME

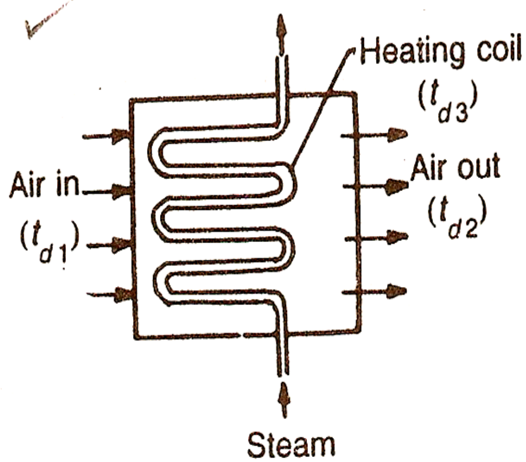



ENTHALPY, Btu / lb Dry Air
WET BULB OR SATURATION TEMP.
52 Btu / lb Enthalpy
80°F Wet Bulb Temperature
14.5 cu ft / lb SPECIFIC VOLUME
35 Btu / lb Enthalpy for 71°F Wet Bulb Temperature
80% 60% Relative Humidity
40%
20%
80°F DRY BULB TEMPERATURE
HUMIDITY RATIO, POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE, °F
SPECIFIC VOLUME, cu ft / lb Dry Air

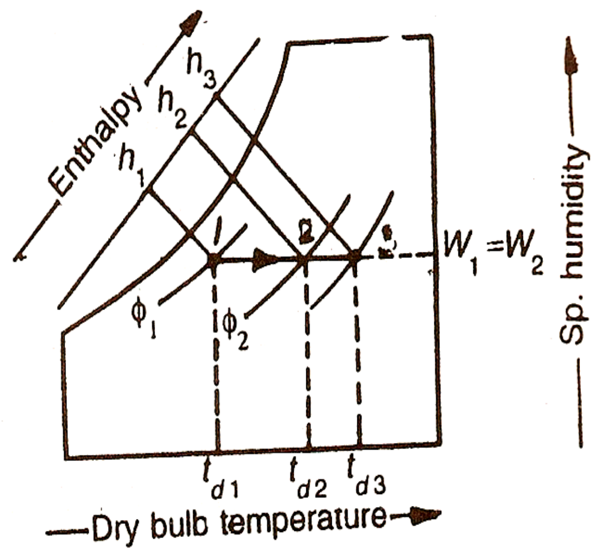
PSYCHROMETRIC PROCESSES

- Sensible heating
- Sensible cooling
- Humidification and dehumidification
- Cooling and dehumidificaton
- Heating and humidification
- Adiabatic mixing of air streams

Sensible Heating



(*a*) Psychrometric process.



(*b*) Psychrometric chart.

Sensible Heating

shown in Fig. The amount of heat added during sensible heating may be obtained from the relation:

Heat added, $q = h_2 - h_1$

$= C_{pa}(t_{d2} - t_{d1}) + W\ C_{ps}\ (t_{d2} - t_{d1})$

$= (C_{pa} + W\ C_{ps})\ (t_{d2} - t_{d1})$

$= C_{pm}\ (t_{d2} - t_{d1})$

The term $(C_{pa} + W\ C_{ps})$ is called humid specific heat (C_{pm}) and its value is taken as 1.022 kJ/kg K.

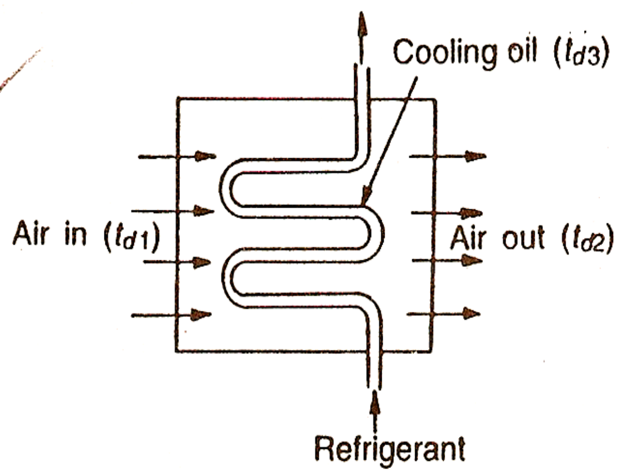
Heat added, $q = 1.022\ (t_{d2} - t_{d1})$ kJ/kg

Note:

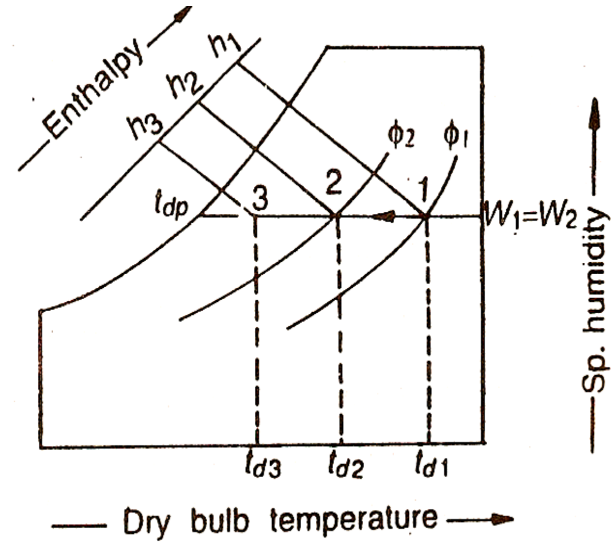
1. For sensible heating, steam or hot water is passed through the heating coil. The heating coil may be electric resistance coil.

2. The sensible heating of moist air can be done to any desired temperature.

Sensible Cooling



(*a*) Psychrometric process.



(*b*) Psychrometric chart.

Sensible Cooling

humidity increases from $\phi_1 to \phi_2$ as shown in Fig. b. the amount of heat rejected during sensible cooling may also be obtained from the relation:

Heat rejected, $q = h_1 - h_2$

$$= C_{pa}(t_{d1} - t_{d2}) + W\ C_{ps}\ (t_{d1} - t_{d2})$$

$$= (C_{pa} + W\ C_{ps})\ (t_{d1} - t_{d2})$$

$$= C_{pm}\ (t_{d1} - t_{d2})$$

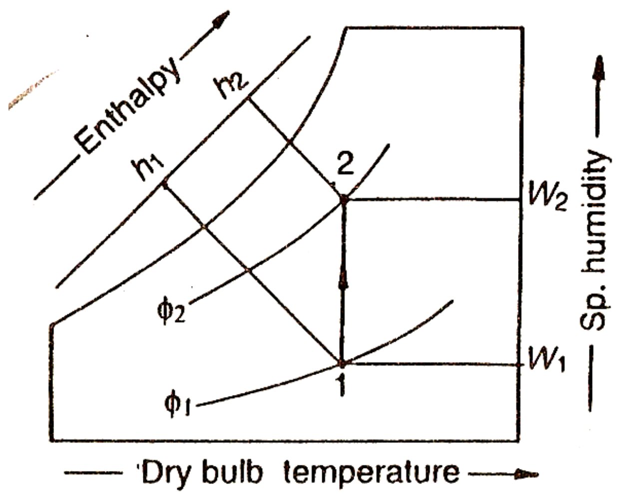
The term $(C_{pa} + W\ C_{ps})$ is called humid specific heat (C_{pm}) and its value is taken as 1.022 kJ/kg K.

Heat added, $q = 1.022\ (t_{d1} - t_{d2})$ kJ/kg

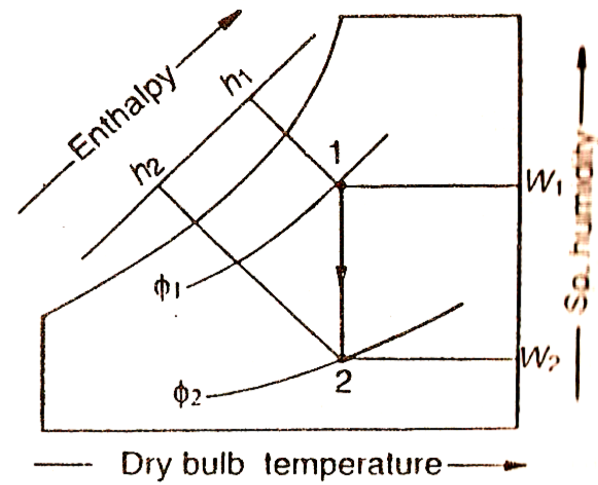
Note:

1. For sensible cooling, the cooling coil may have refrigerant, cooling water or cool gas flowing through it.
2. The sensible cooling can be done only upto the dew point temperature (t_{dp}) as shown in fig b. the cooling below this temperature will result in the condensation of moisture.

Humidification and Dehumidification



(a) Humidification.

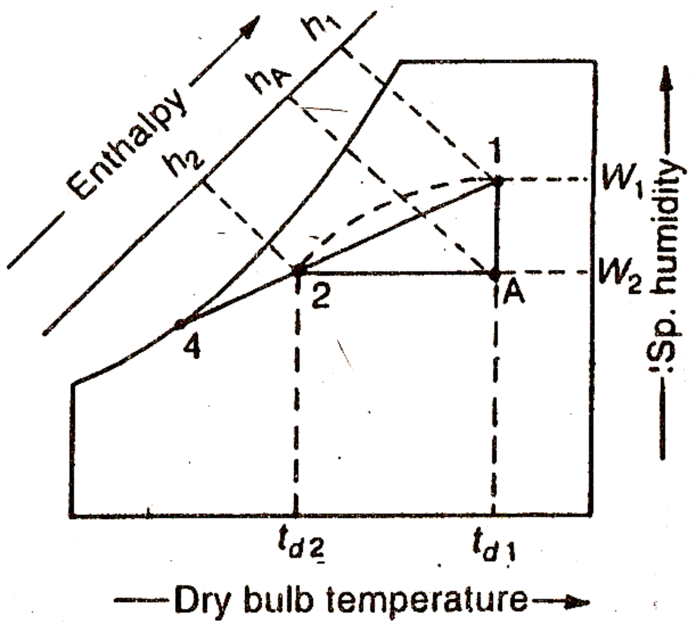


(b) Dehumidification.

$LH = (h_2 - h_1) = h_{fg} (W_2 - W_1)$

$LH = (h_1 - h_2) = h_{fg} (W_1 - W_2)$

Cooling and Dehumidification



(a)

$$q = h_1 - h_2 = (h_1 - h_A) + (h_A - h_2) = LH + SH$$

Where,

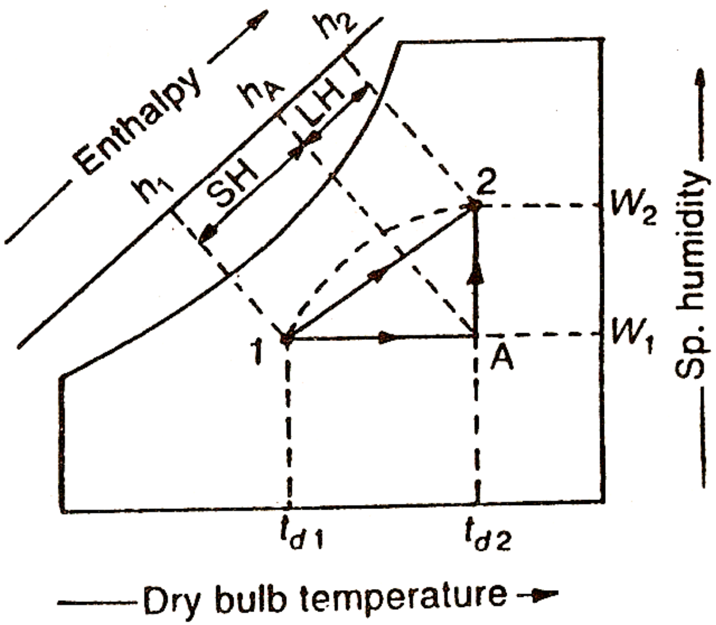
$LH = h_1 - h_A$ = latent heat removed due to condensation of vapour of the reduced moisture content $(W_1 - W_2)$, and

$SH = h_A - h_2$ = Sensible heat removed

We know that sensible heat factor,

$$SHF = \frac{Sensible heat}{Total heat} = \frac{SH}{LH + SH} = \frac{h_A - h_2}{h_1 - h_2}$$

Heating and Humidificaton



$$q = h_2 - h_2 = (h_2 - h_A) + (h_A - h_1) = LH + SH$$

Where,

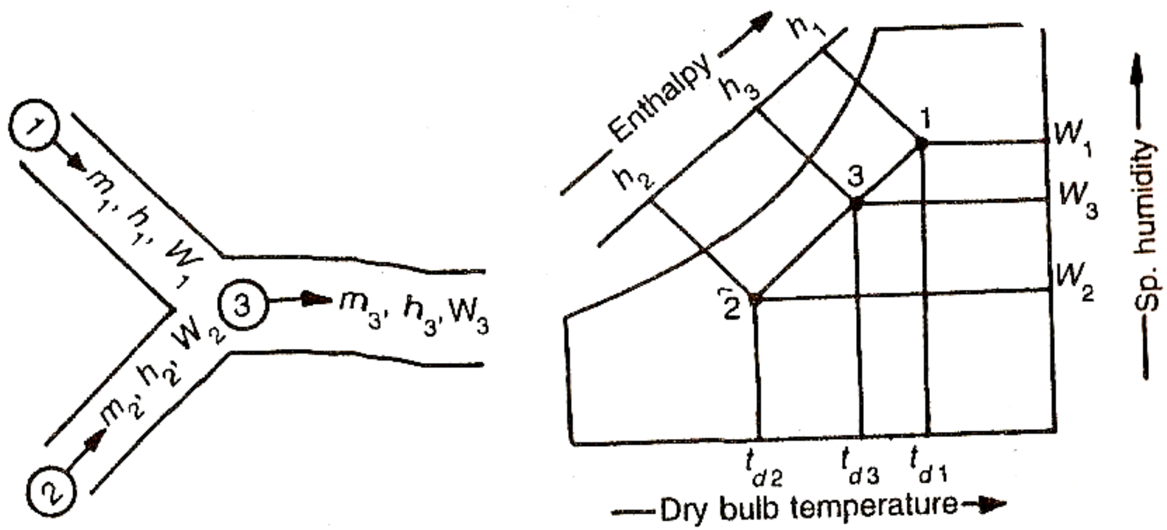
$LH = h_2 - h_A$ = latent heat of vaporization of the increased moisture content $(W_1 - W_2)$, and

$SH = h_A - h_1$ = Sensible heat added

We know that sensible heat factor,

$$SHF = \frac{Sensibleheat}{Totalheat} = \frac{SH}{LH + SH} = \frac{h_A - h_1}{h_2 - h_1}$$

Mixing of air streams



m_1 = Mass of air entering at 1

h_1 = Enthapy of air entering at 1

W_1 = Specific humidity of air entering at 1

m_2, h_2, W_2 = Corresponding values of air entering at 2 and

m_3, h_3, W_3 = Corresponding values of the mixture leaving at 3

Assuming no loss of nthlpy and specific humidity during the air mixing process, we have

For the mass balance,

$$m_1 + m_2 = m_3 \qquad \text{........(1)}$$

For the energy balance,

$$m_1h_1 + m_2h_2 = m_3h_3 \qquad \text{........(2)}$$

And for the mass balance of water vapour,

$$m_1W_1 + m_2W_2 = m_3W_3 \qquad \text{........(3)}$$

Substituting the value of m_3 from equation (1) in equation (2),

$$m_1h_1 + m_2h_2 = (m_1 + m_2)h_3 = m_1h_3 + m_2h_3$$

$$m_1h_1 - m_1h_3 = m_2h_3 - m_2h_2$$

$$m_1(h_1 - h_3) = m_2(h_3 - h_2)$$

$$\frac{m_1}{m_2} = \frac{(h_3 - h_2)}{(h_1 - h_3)} \qquad \text{........(4)}$$

Similarly, substituting the value of m_3 from equation (1) in equation (3), we have

$$\frac{m_1}{m_2} = \frac{(W_3 - W_2)}{(W_1 - W_3)} \qquad \text{........(5)}$$

$$\frac{m_1}{m_2} = \frac{(h_3 - h_2)}{(h_1 - h_3)} = \frac{(W_3 - W_2)}{(W_1 - W_3)} \qquad \text{........(6)}$$

Use of Psychrometric Chart to Evaluate Complex Air-Conditioning Processes

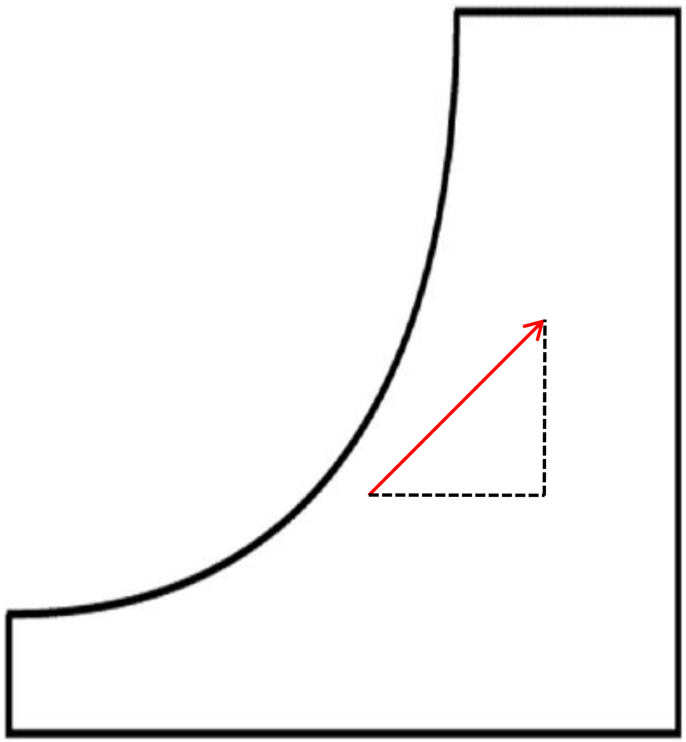
Sensible heating or cooling

- A psychrometric process that involves the increase or decrease in the temperature of air without changing its humidity ratio
- Example: passing moist air over a room space heater and of kiln air over the heating coils

Thermal energy required , $q = \dot{m}(H_B - H_A)$

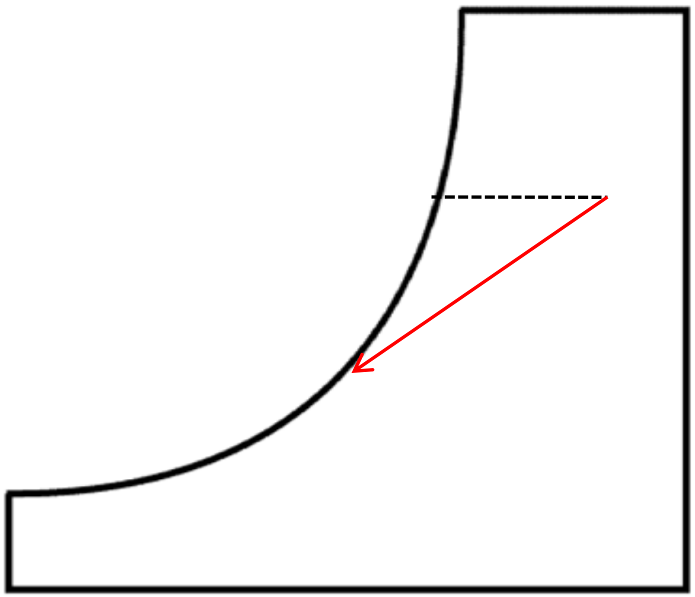
Heating and Humidifying

- a psychrometric process that involves the simultaneous increase in both the dry bulb temperature and humidity ratio of the air



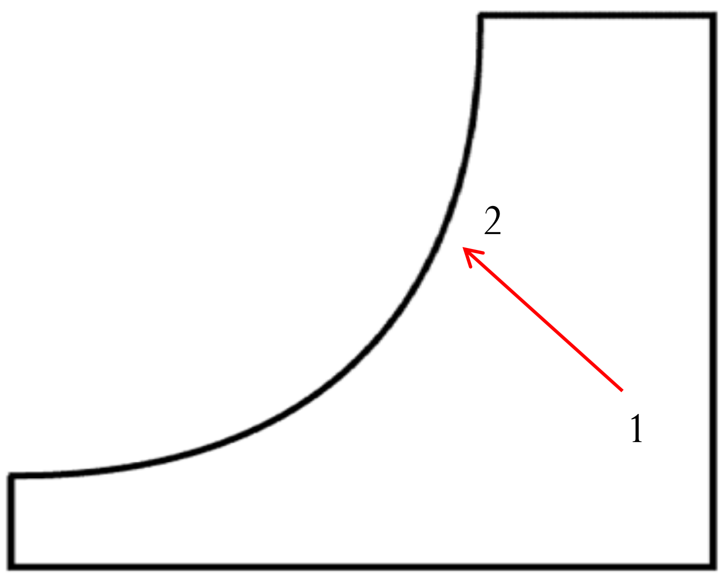
Cooling and Dehumidifying

- a psychrometric process that involves the removal of water from the air as the air temperature falls below the dew point temperature



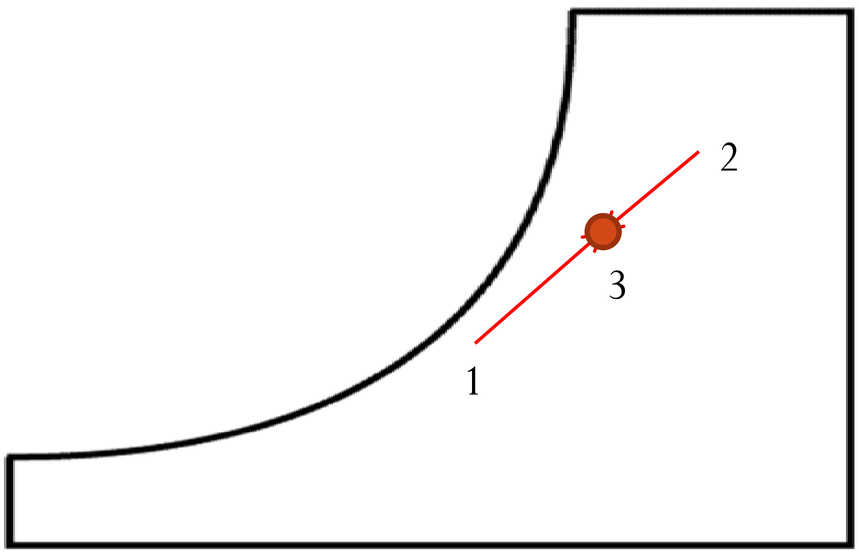
Adiabatic/Evaporative Cooling

- a psychrometric process that involves the cooling of air without heat loss or gain
- Sensible heat lost by the air is converted to latent heat in the added water vapor

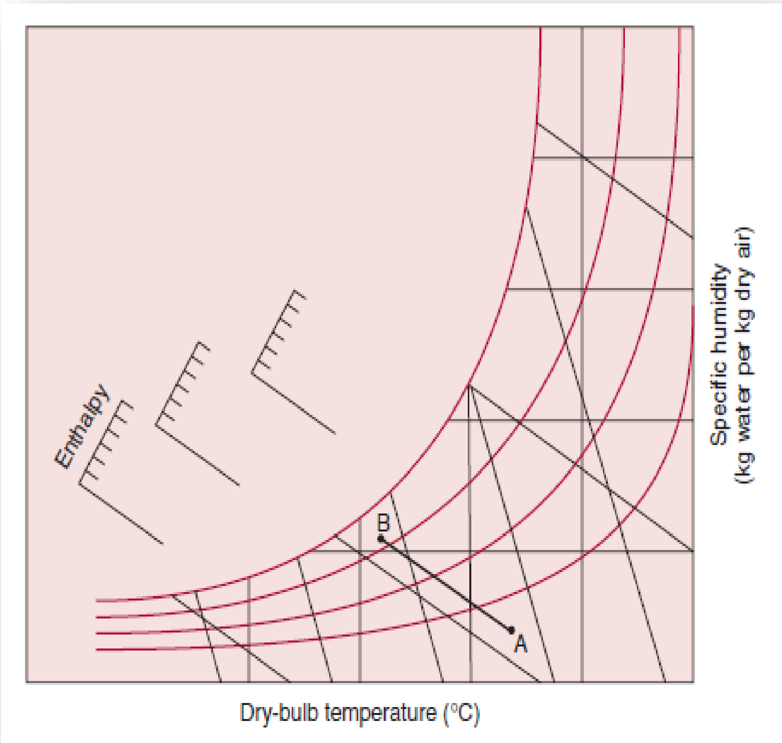


Mixing of Moist Air Stream

- A psychrometric process that involves no net heat loss or gain during the mixing of two air streams
- Represented by a straight line divided in inverse proportion to the weights of the individual air quantities



Drying



- drying process can be described on the psychrometric chart as an adiabatic saturation process

- The heat of evaporation required to dry the product is supplied only by the drying air; no transfer of heat occurs due to conduction or radiation from the surroundings

THANK YOU